The Role of Variability in Mine Burial Prediction

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LONG-TERM GOALS

The ultimate long-term goal of the ONR Mine Burial Prediction (MBP) program is the development of mine burial probability models that incorporate dynamic coupled processes, seafloor material properties, and different mine types. A second major thrust is on short-term applied research that will provide Fleet Aids for the operational Navy. The short-term effort will provide the operational Navy with improved mine burial predictive capabilities by using existing models and an enhanced understanding of environmental databases and seafloor geotechnical properties. An important part of that effort will involve designing user interfaces that will both display the complexities and uncertainties of the problem while remaining user-friendly for the sailor. As better models are developed during the course of the program, they will be incorporated into the existing predictive systems.

OBJECTIVES

Objectives during the past year were (1) to help organize meetings of MBP investigators, (2) participate in research cruises in 2002 and plan for fieldwork in 2003, (3) work on the NATO Mine Burial Assessment Specialist Team (MBAST), (4) assist in starting up the MBP website at the University of New Hampshire, and (5) examine in detail how uncertainty propagates through a mine burial model.

APPROACH

Most of the above objectives were procedural and need no explanation. In order to look at uncertainty propagation I adapted an idea presented by Linwood Vincent to the MBAST group in 2001. IMPACT28 is one of the current models available to predict the extent of impact burial during mine deployment. Early results by other MBP investigators have shown this model to be imperfect, but we are using it as a means to examine effects of uncertainty. The results should apply to better models as well as to IMPACT28.

When considering a solid cylinder (no tapered ends) IMPACT28 has 11 independent variables. For each of these variables we chose a value and a range of uncertainty. For instance, we chose the mine mass to be 500kg with an uncertainty of .10 (10%). For each variable we specified either (1) no uncertainty, (2) an even distribution of input values within the uncertainty range, or (3) a Gaussian

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14. ABSTRACT
The ultimate long-term goal of the ONR Mine Burial Prediction (MBP) program is the development of mine burial probability models that incorporate dynamic coupled processes, seafloor material properties, and different mine types. A second major thrust is on short-term applied research that will provide Fleet Aids for the operational Navy. The short-term effort will provide the operational Navy with improved mine burial predictive capabilities by using existing models and an enhanced understanding of environmental databases and seafloor geotechnical properties. An important part of that effort will involve designing user interfaces that will both display the complexities and uncertainties of the problem while remaining user-friendly for the sailor. As better models are developed during the course of the program, they will be incorporated into the existing predictive systems.

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distribution of uncertainty within the range. 500 sets of 11 input variables were then run to produce a distribution of impact burial results.

WORK COMPLETED

(1) I organized – with Scott Jenkins and Doug Inman of Scripps – the second annual MBP investigators meeting at Scripps in January. We wrote and circulated a report of the meeting. With Joe Fernando (ASU), I organized a meeting of MBP modelers and laboratory experimenters in Tempe in March. A questionnaire was circulated to all modelers and the results collated and distributed. (2) I participated in 2 MBP research cruises. Phil Valent and Wayne Dunlap organized the Corpus Christi Impact Burial test cruise in May. We surveyed and sampled the Navy mine warfare training area off the Gulf coast and performed 13 drops of the new instrumented impact mine package developed by NRL. I was a Co-Chief scientist of a cruise around the Martha's Vineyard Coastal Observatory (MVCO), organized with John Goff and Peter Traykovski. I was in charge of vibracoring (Figure 1). We collected 35 cores in sandy sediments around MVCO. (3) I attended MBAST meetings in Paris (Feb) and La Spezia (July). I presented a summary of current Subsequent Burial models in La Spezia and agreed to write a report on my uncertainty work for the group. I also presented a preliminary database model – using Corpus Christi data – for mine burial experiments. (4) I have been supplying content for the MBP website, but scheduling conflicts so far have slowed down this process. I hope to have much of this summer's cruise data available for other MBP participants on the web as it is ready. (5) I developed a program to generate sets of input variables for IMPACT28 and ran some preliminary tests (see Results below). I am beginning to work on extending this concept to a 2D map view.

RESULTS

A simple result that illustrates an important point is presented in Figures 2 and 3. In order to see how much difference a good guess of input parameters might be from a simple guess, we made 5 IMPACT28 runs (of 500 separate models) assuming that all of the unknowns had an even distribution within the specified limits. We then ran 5 more cases assuming a better knowledge of the true value of the variables – Gaussian distributions. Results of one run of each case are shown in Figure 2 and cumulative plots of all 10 runs are shown in Figure 3. The results are plotted as a function of the percentage of the mine volume exposed above the sediment surface. A single run of IMPACT28 with the same inputs and no uncertainty yielded an exposed volume of 29%.

Both systems of models produce results that are largely normal distributions, with the Gaussian models yielding a more narrow range of results. For a cylinder of the size we modeled, the limit of detectability – depending on sonar performance – is about 25%. If any less of the mine is exposed, it is not detectable. The cumulative plots illustrate that although the "no uncertainty" model produced an answer that indicated a detectable mine, almost 40% of the results were undetectable (<25%). In the Gaussian case this number drops to near 10%.

These results illustrate how important it is to accurately assess our knowledge (or lack of it) of the inputs to our MBP models. One run of the purely deterministic model produces a detectable result. Models with some uncertainty, but assuming we probably know the values pretty well, suggest a 10% chance of non-detectability. The poorly defined case, however, points to a very large chance that there may be undetectable mines in the area of operation.

IMPACT/APPLICATIONS

The modeling and field studies will eventually result in an improved ability to predict the fate of mines on the seafloor. We will also develop much improved methods for presenting stochastic data to operators in the Fleet.

TRANSITIONS

None so far.

RELATED PROJECTS

In my capacity as Coordinator of the Mine Burial Prediction program I am working closely with all of the other MBP investigators. See www.mpb.unh.edu for a list.

Figure 1. Vibracoring operations off Martha's Vineyard. Photograph illustrates a vibracoring system being deployed off the stern of R/V CAPE HENLOPEN.

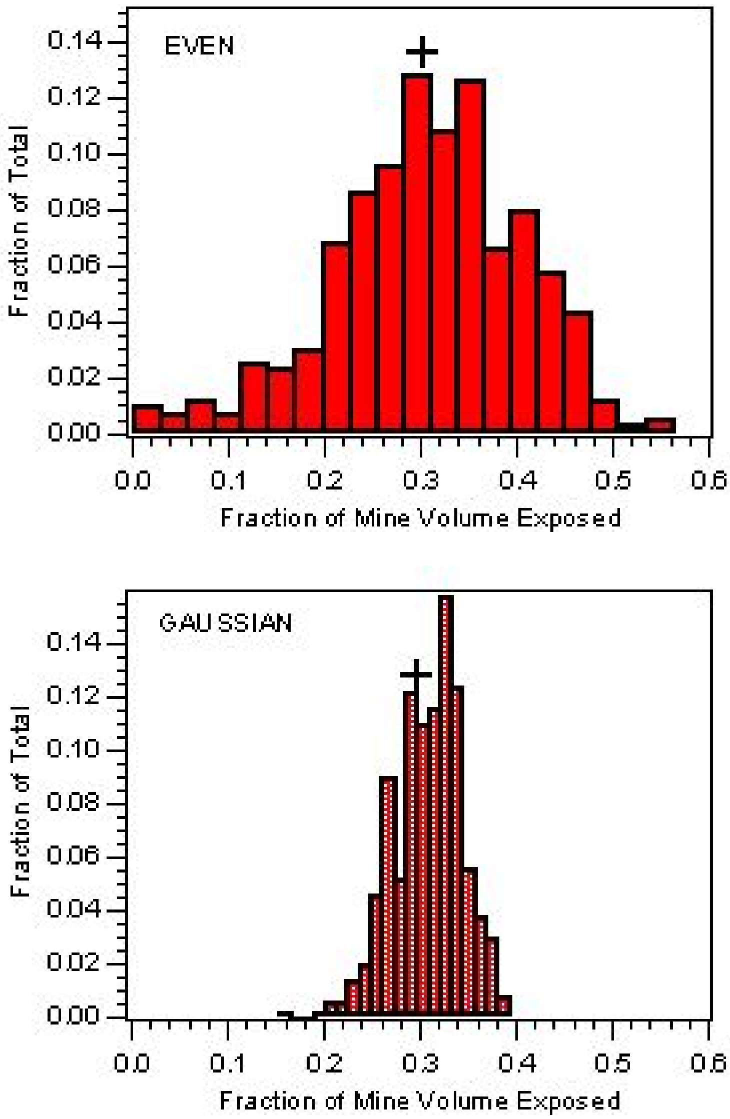

Figure 2. Fraction of mine volume exposed versus portion of 500 total runs.Two histograms illustrating the results of 2 runs of 500 IMPACT28 models each. Inputs in the upper figure were assigned an even distribution across defined limits. In the case of the lower figure, the distribution of uncertainty was Gaussian. Both results show a semi-normal distribution of predictions, but the Gaussian curve is much narrower.

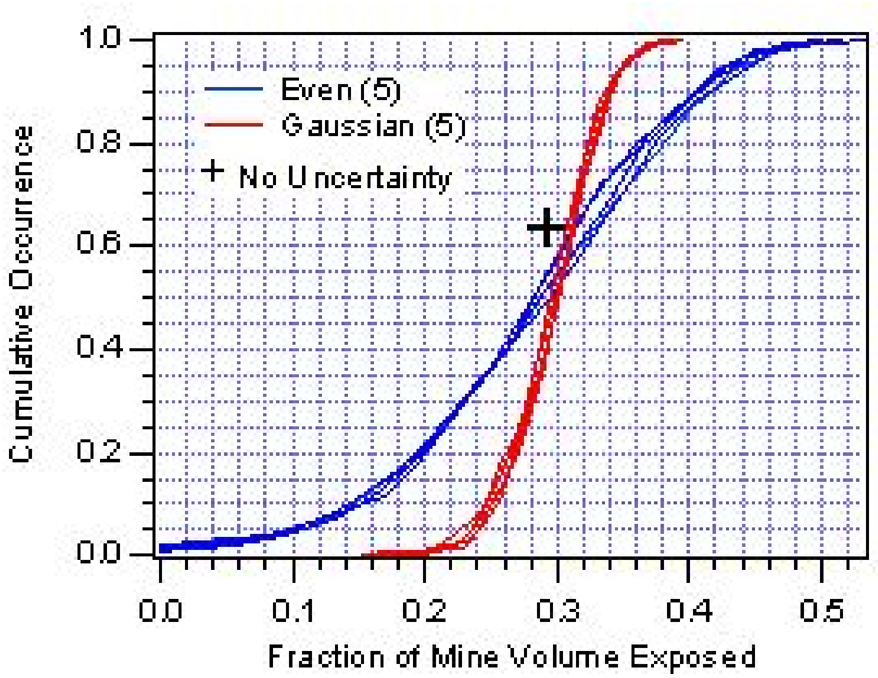

Figure 3. Cumulative plots of the results of 5 Even uncertainty distributions and 5 Gaussian uncertainty distributions. The cross shows the value (29%) of a single calculation assuming no uncertainty. The important result is that in the Even case almost 40% of the results show less than 25% of the mine exposed (and so – undetectable). In the Gaussian case that number drops to 10% reflecting a better knowledge of the mining environment.